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NUSC Technical Report 5635

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NUSC Technical Report 5635

Generic FACT

Henry Weinberg
Special Projects Department

1 June 1977

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PREFACE

This work was accomplished under NUSC Project No. B-650-02, "Underwater Acoustic / Environmental Modeling and Data Bank for Sonar Systems Design and Performance Prediction" (U), Principal Investigator, F. R. DiNapoli (Code 312), and Navy Subproject and Task No. SF-52-522-701. The sponsoring activity is the Naval Sea Systems Command, Program Manager, A. P. Franceschetti (SEA 06H1-4).

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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Bottom Loss Discontinuities
False Caustics
Generic Fast Asymptotic Coherent Transmission (FACT)
Generic Sonar Model
Subsurface Channels

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A Generic Sonar Model is used to investigate predictions generated by the Fast Asymptotic Coherent Transmission (FACT) Loss Model. Results indicate that FACT may produce questionable results in certain special situations. Possible improvements to FACT are suggested.

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GENERIC FACT

INTRODUCTION

The Generic Sonar Model is a computer program designed to aid analysts predict the performance of sonar systems. Included in the Generic Sonar Model's library of subroutines is a modified version of the Fast Asymptotic Coherent Transmission Model[1] (FACT). The modified version, called Generic FACT, was found to be accurate in the majority of cases investigated, but not in all.

Three questionable predictions by Generic FACT documented in this paper pertain to bottom reflection coefficients, false caustics, and subsurface channels. The first prediction should be corrected by replacing the bottom reflection coefficient subroutine, and the second by changing one line of FORTRAN code. Correcting the third prediction, however, may require a substantial effort.

One of the desirable features of the original FACT Model is that predictions made at one installation can be reproduced at another. However, if the user makes the changes recommended in this report, he will lose consistancy. A possible solution to this dilemma would be to implement the same changes at all installations, but this is presently impractical.

GENERIC SONAR MODEL

The Generic Sonar Model is a computer program designed to provide systems developers and technologists with a comprehensive modeling capability for evaluating the performance of sonar systems and investigating the ocean environment in which they operate. Specific uses of the Generic Sonar Model include the following:

a. Analysis in which the relative performance of sonar systems are compared

b. Optimization of individual sonar designs

c. Support of sonar operational trainers

d. Support of engagement models

e. Comparison of existing acoustic models

f. Development of improved acoustic models.

Only a discussion of "e" follows because the main thrust of this report is to discuss the comparison of existing acoustic models.

Comparison of existing acoustic models is accomplished through modular design, adhering to a strict Generic format, and using overlaying techniques. For example, an option presently available in many propagation programs allows one to compare bottom reflection coefficient models by simply replacing the bottom reflection coefficient subroutine. The Generic Sonar Model allows the user to replace entire propagation loss programs as well. Thus, a sonar analyst can choose appropriate building blocks from a library of subroutines in order to obtain a best cost/accuracy configuration for the particular study at hand.

The Generic Sonar Model will not be ready for general distribution until it is documented. However, local usage at NUSC has uncovered some disturbing predictions by FACT that warrant dissemination now. These predictions were first discovered using Generic FACT and then verified against the standard version's output to ensure that Generic modifications were not a source of error.

BOTTOM REFLECTION COEFFICIENT DISCONTINUITIES

Most computer programs designed to model acoustic propagation in the ocean are optimized to predict propagation loss versus position at one frequency, whereas sonar system analysts require propagation loss versus frequency with position as the parameter. Errors are readily found by investigating discontinuities in plotted outputs. As a result, propagation loss models are "debugged" at a constant frequency, while analysts who are unfamiliar with the idiosyncrasies o an acoustic model inadvertantly optimize their systems at frequencies where the computed propagation loss changes abruptly. Obviously, the design of a bottom bounce sonar should not be based on a bottom reflection coefficient model that displays significant discontinuities at frequencies within the operating band.

A useful feature of the Generic Sonar Model is the ability to display the output of its basic subroutines versus frequency. Upon applying this option to the Generic version of the FACT bottom reflection coefficient subroutine, one sees from figure 1 that the subroutine's output is riddled with discontinuities. Many of these discontinuities fall at sonar operational frequencies.

It is, therefore, recommended that the FACT bottom reflection coefficient model be smoothed by first removing the code that leads to nonmonotonic discontinuities and, then, adding a linear interpolation between the remaining breakpoints. Alternatively, one could use the RAYMODE bottom reflection coefficient model that is coded by Yarger.[2] A sample output is illustrated in figure 2.

The bottom reflection coefficient discontinuities were apparent to many FACT users who proceeded to find the origin independently and without Generic-like models. However, the next questionable prediction to be discussed could not have been found so easily and serves to illustrate the power of the Generic Sonar Model.

FALSE CAUSTICS

Besides Generic FACT, a second propagation loss subroutine called the Multipath Expansion[3] resides in the Generic library. The two subroutines agreed reasonably well in the majority of cases compared, although FACT was approximately 20 times faster. Both were exercised for the sound profile in figure 3. Agreement was satisfactory except when both source and receiver were placed at a depth of 640 ft (195.072 m). (See figures 4 and 5.) This section is concerned with differences within 10 kyd (9.144 km) in range; the next section will discuss the more significant differences beyond 10 kyd (9.144 km).

As stated earlier, abrupt changes in propagation loss tend to indicate error. Originally, Generic FACT did not show the bump of 4 kyd (3.6576 km), and so it was thought that the Multipath Expansion was at fault. The corresponding ray diagram (figure 6), on the other hand, revealed a strong focusing effect at the point in question, suggesting that the increase in intensity was real.

The Generic Sonar Model is structured so that individual contributions to the acoustic pressure, eigenrays, can be examined individually. It was soon discovered that Generic FACT generated a family of eigenrays corresponding to a false caustic not generated by the Multipath Expansion. This family of relatively high intensity masked the caustic phenomenon.

The reader may wish to omit the remainder of this section which requires a detailed knowledge of FACT.

According to the NUSC listing of FACT,[1] the FORTRAN card

```
15 IF ((THETC.LE.THMAX).AND.(THETC.GE.THMIN)) GO TO (30,35), IGTYP
INSTOR93
```

is responsible for the questionable eigenrays.

Here

THETC is the angle at which a caustic intersects depth Y(K2),

THMIN, THMAX are angular bounds of a group of rays, and

IGTYP equals 2, indicating that the range of the rays in the group is fit with the parabola,

R = A(1) + A(2)*DTHC + A(3)*DTHC**2

A necessary condition for caustics to occur is

DR/DDTHC = A(2) + 2.0*A(3)*DTHC = 0

so that

DTHC = -A(2)/(2.*A(3)) INSTOR96

and

THETC = THMIN + DTHC**2 INSTOR97

In order for the caustic to belong to the group, the inequality

0 < DTHC < (THMAX-THMIN)**0.5

must be satisfied. But, instead suppose that DTHC is small and negative. Then INSTOR 93 would incorrectly place the false caustic in the group. However, when the additional test that DTHC be positive was inserted in Generic FACT, the questionable eigenrays disappeared and the true caustic became visable.

SUBSURFACE CHANNELS

FACT incorporates asymptotic techniques in order to model low frequency diffraction effects not treated by classical ray theory. As this last example will demonstrate, this technique is inappropriate when the source and receiver lie within a weak subsurface channel.

Again consider the sound speed profile in figure 3. A weak subsurface channel lies below the 100 ft (30.48 m) surface duct and extends to a depth of 1265 ft (385.572 m). Figure 7 is a ray diagram for the 640 ft (195.072 m) depth source and consists of source angles ranging from -20° to $+20^\circ$ in $1/2^\circ$ steps. Bottom bounce rays were terminated at their second reflection in the ray diagram for illustrative purpose. One sees that the 0^{o} ray is trapped in the subsurface channel while the $\pm 1/2^{o}$ rays escaped.

By applying the eigenray printout option of the Generic Sonar Model to investigate the 45 kyd (41.148 km) region, we found that the Generic FACT was dominated by subsurface channel energy (figure 4) while the Multipath Expansion was bottom bounce limited (figure 5). Analytic investigation supported by FFP[4] and RAYMODE[5] predictions shown in figures 8 and 9, respectively, substantiate the Multipath Expansion.

Possible improvement to Generic FACT predictions could be achieved by smoothing weak subsurface channels out of sound speed profiles or by adding specialized logic similar to the FACT surface duct model.

SUMMARY

This report cautions the reader when using FACT in certain applications. Possible improvements are suggested, but there does not seem to be any practical way of implementing these modifications universally. Perhaps an interlaboratory committee such as the Panel on Standard Sonar Models (POSSM) could be tasked to distribute standard model updates at least throughout the Navy. Secondly, this report describes briefly a Generic Sonar Model and how it may be used to localize discrepancies in other acoustic models. Detailed documentation is in preparation.

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4. F. R. DiNapoli, Fast Field Program for Multilayered Media, NUSC Technical Report 4103, 26 August 1971.

5. G. A. Leiberger, "A Combined Ray Theory-Normal Mode Approach to Long Range Low Frequency Propagation Loss Prediction" (U), NUSC Technical Memorandum PA-0109-71, 13 August 1971 (CONFIDENTIAL).

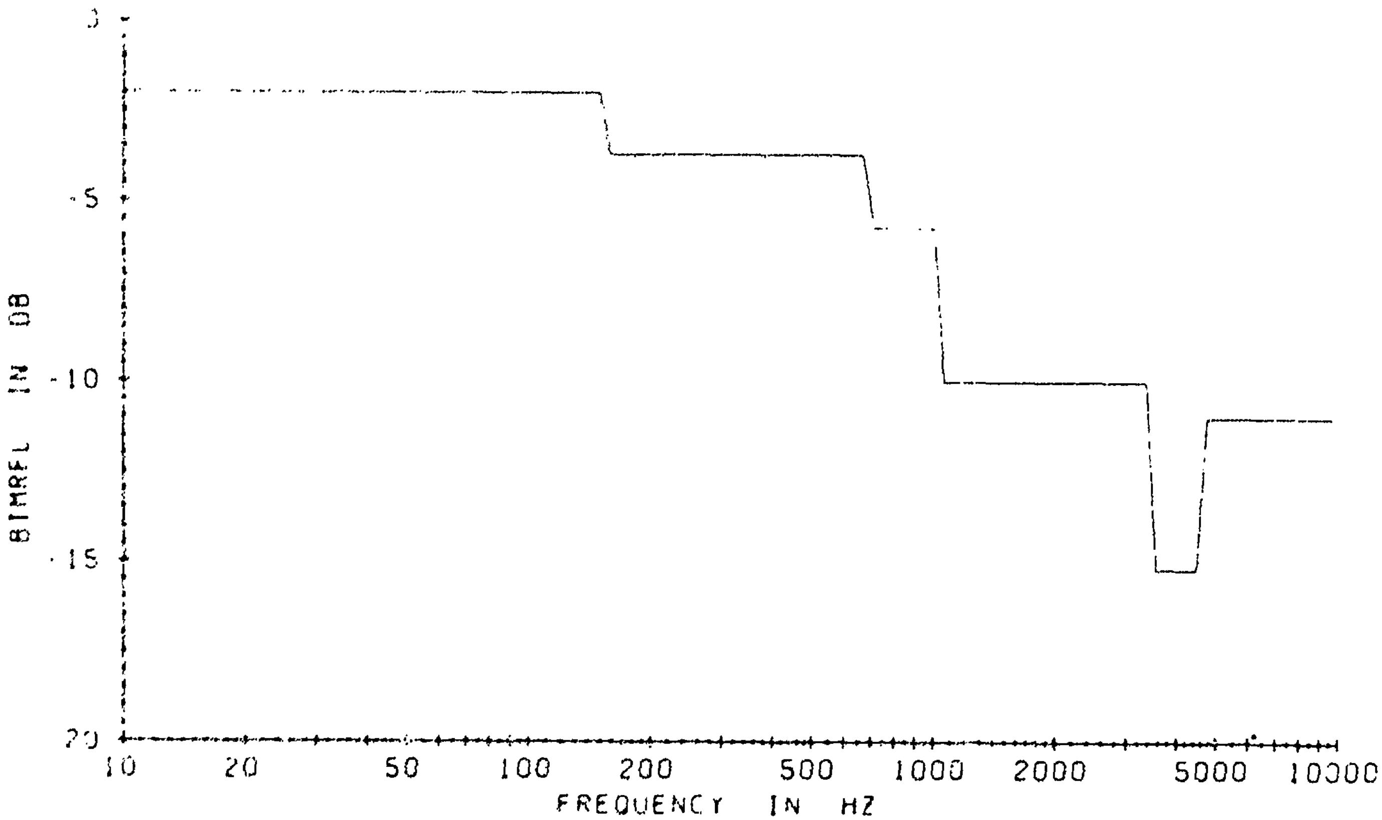

Figure 1. FACT Bottom Loss Versus Frequency at 10° Grazing Angle for MGS Province 4

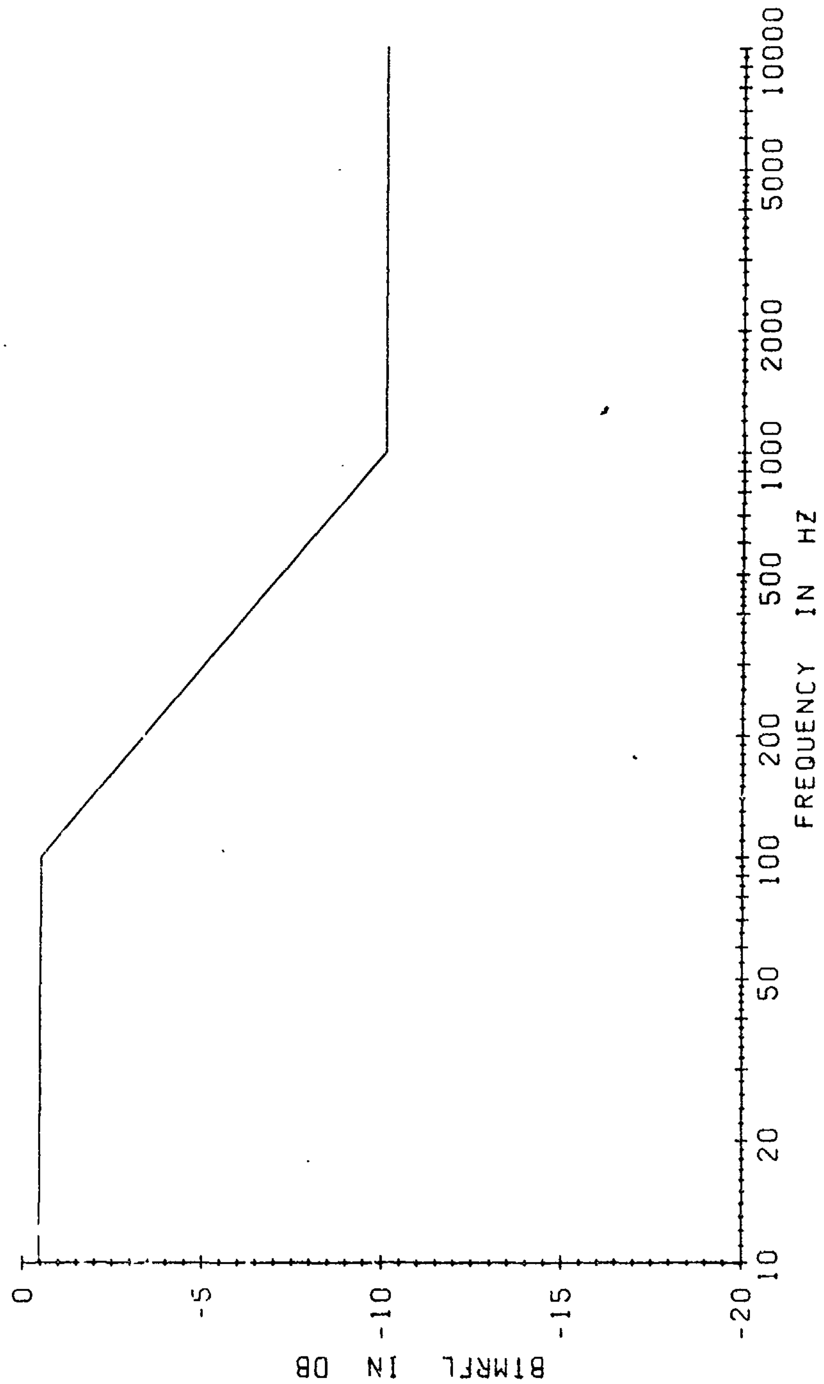

Figure 2. RAYMODE Bottom Loss Versus Frequency at 10^{o} Grazing Angle for MGS Province 4

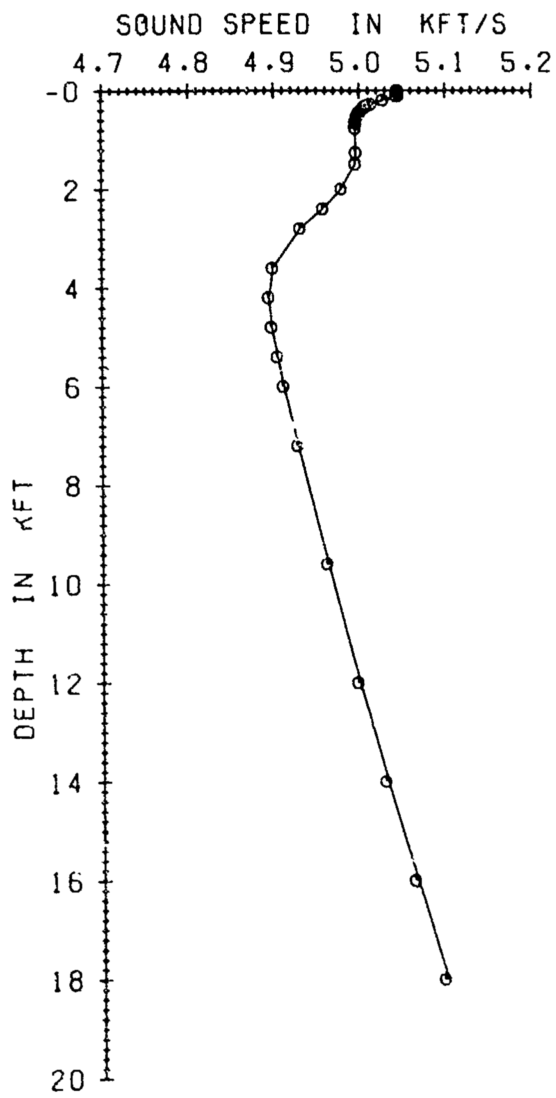

Figure 3. Sound Speed Versus Depth

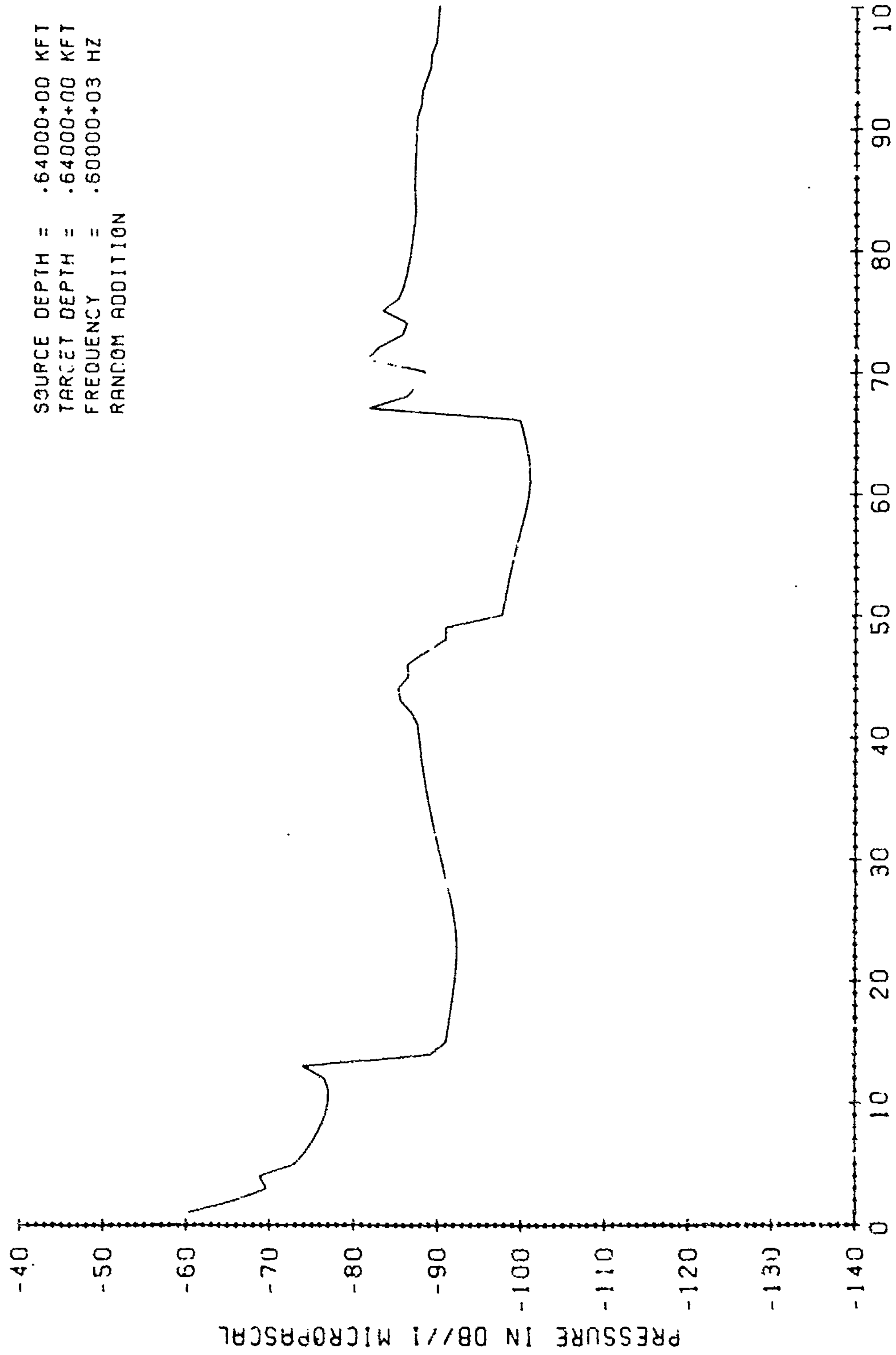

Figure 4. Propagation Loss Versus Range Computed by Generic FACT

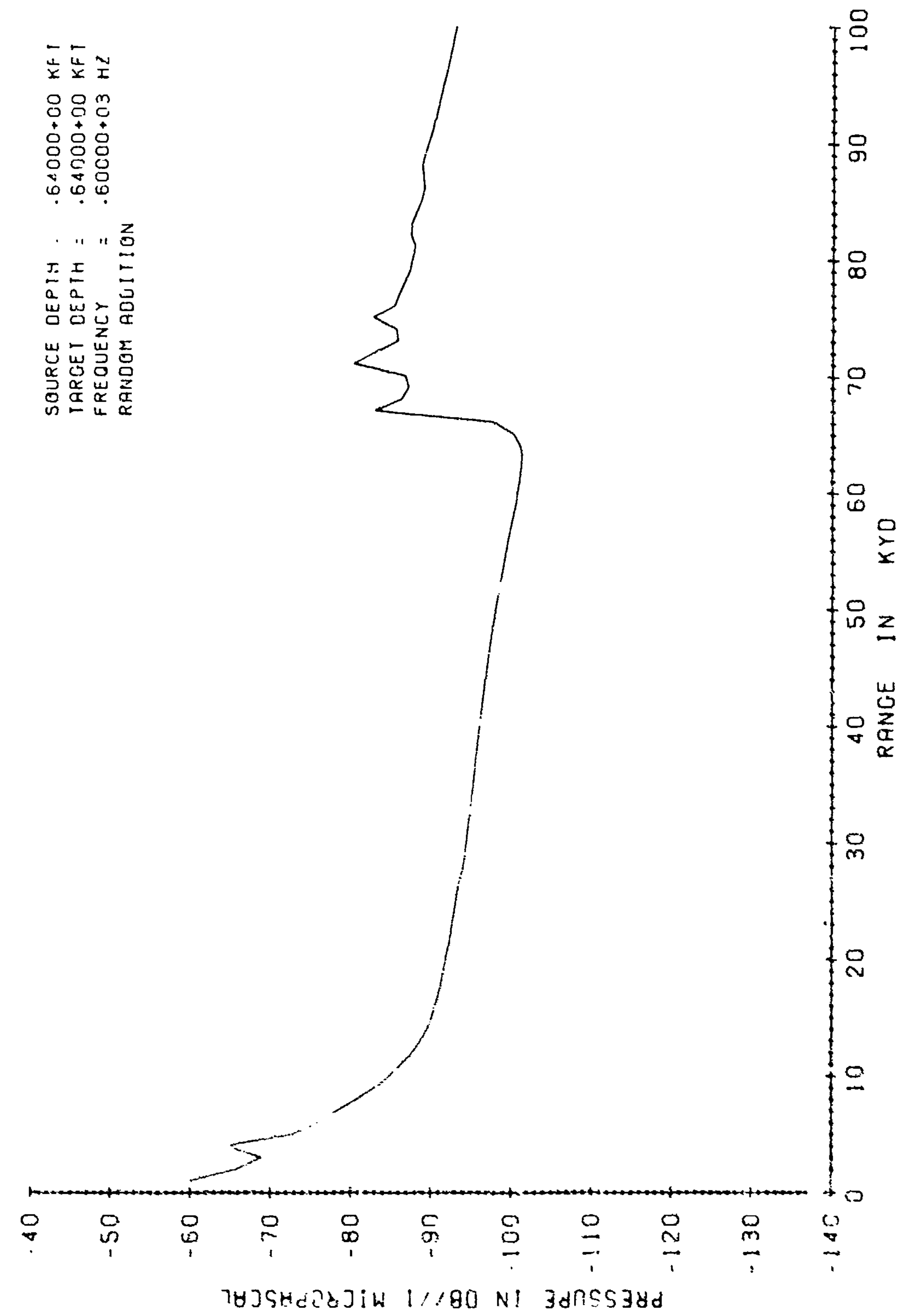

Figure 5. Propagation Loss Versus Range Computed by the Multipath Expansion

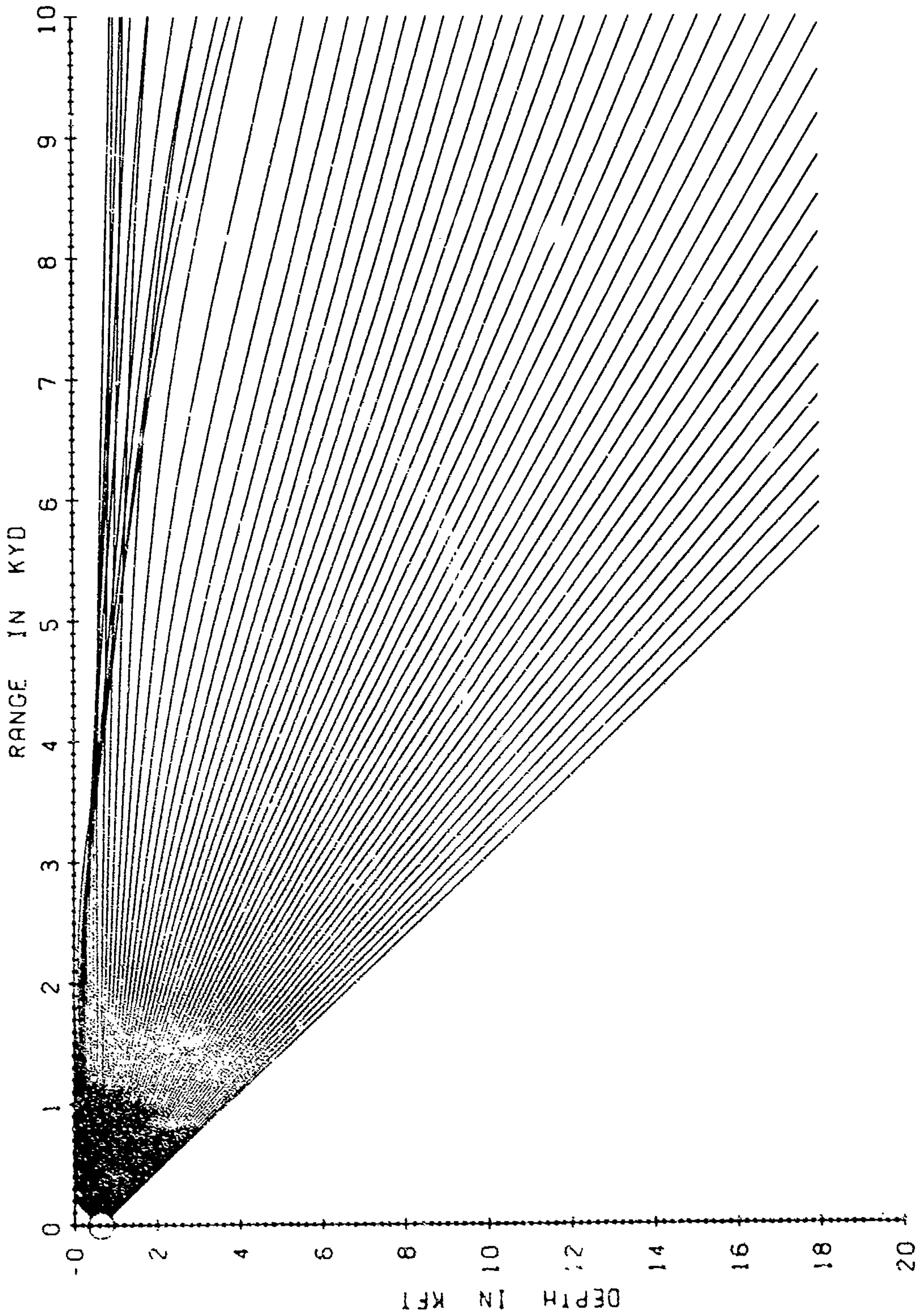

Figure 6. Ray Diagram for a 640 ft (195.072 m) Source

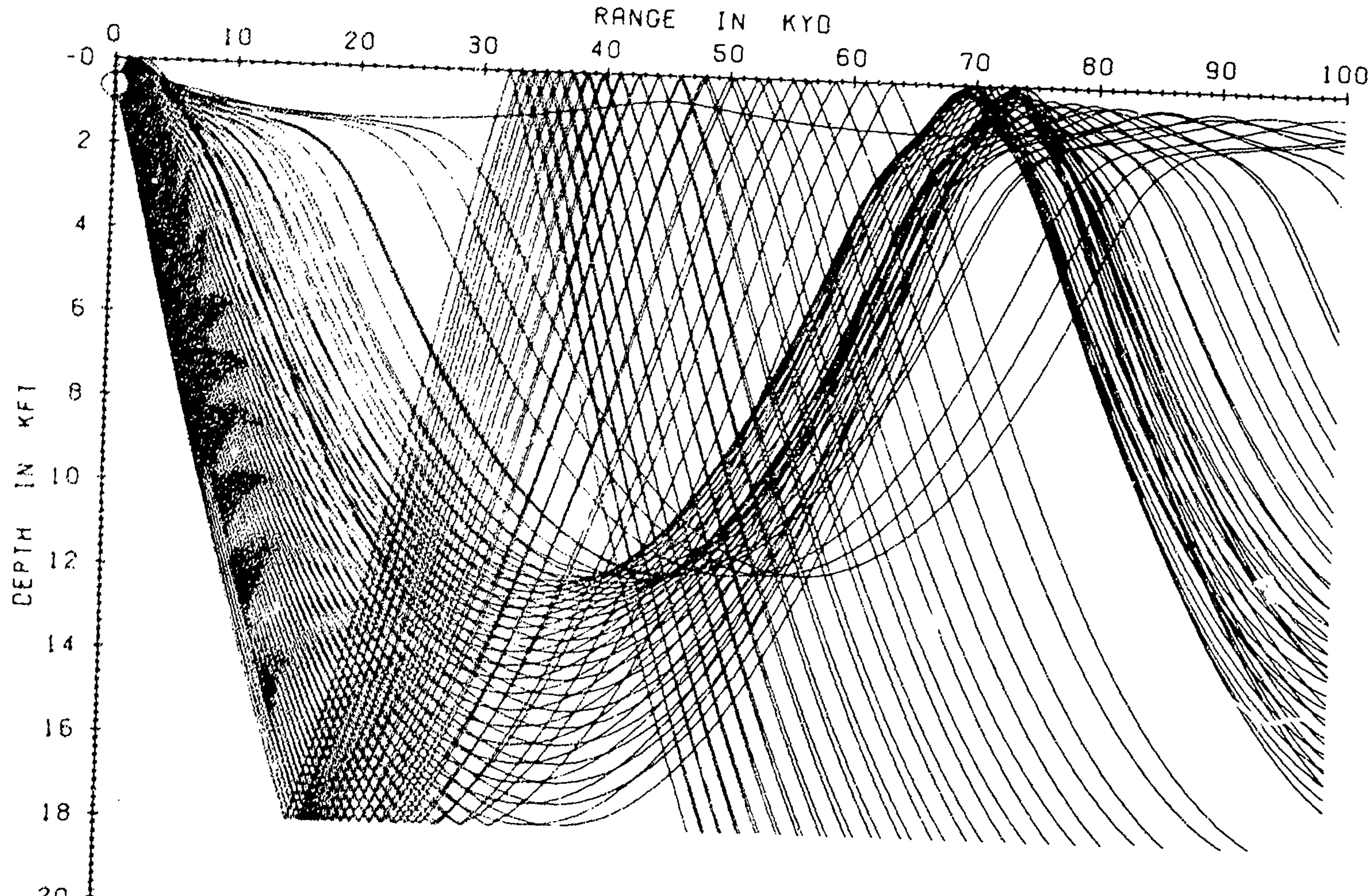

Figure 7. Ray Diagram for a 640 ft (195.072 m) Source, Including Source Angles from -20° to +20° in 1/2° Steps

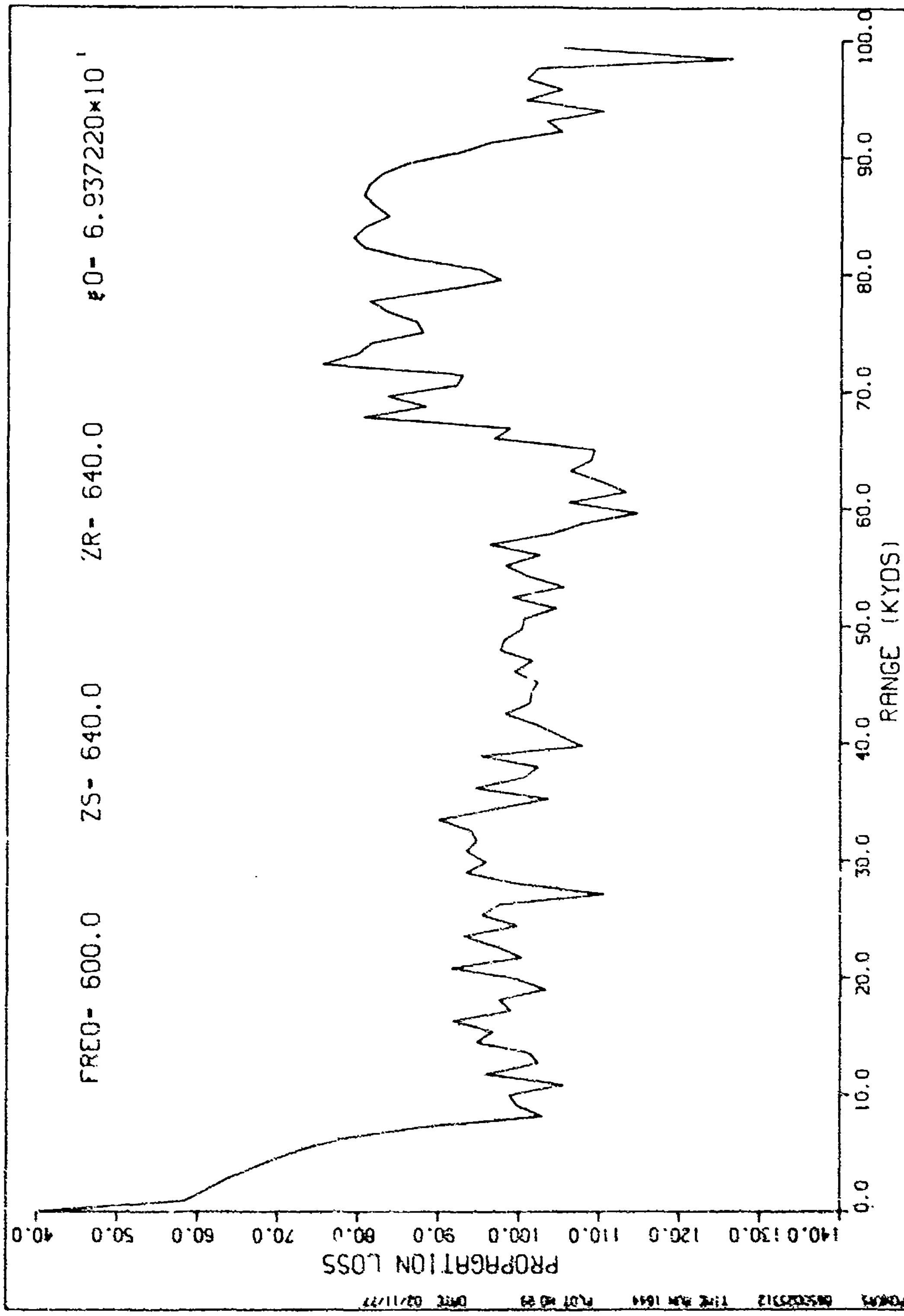

Figure 8. Propagation Loss Versus Range Computed by FFP

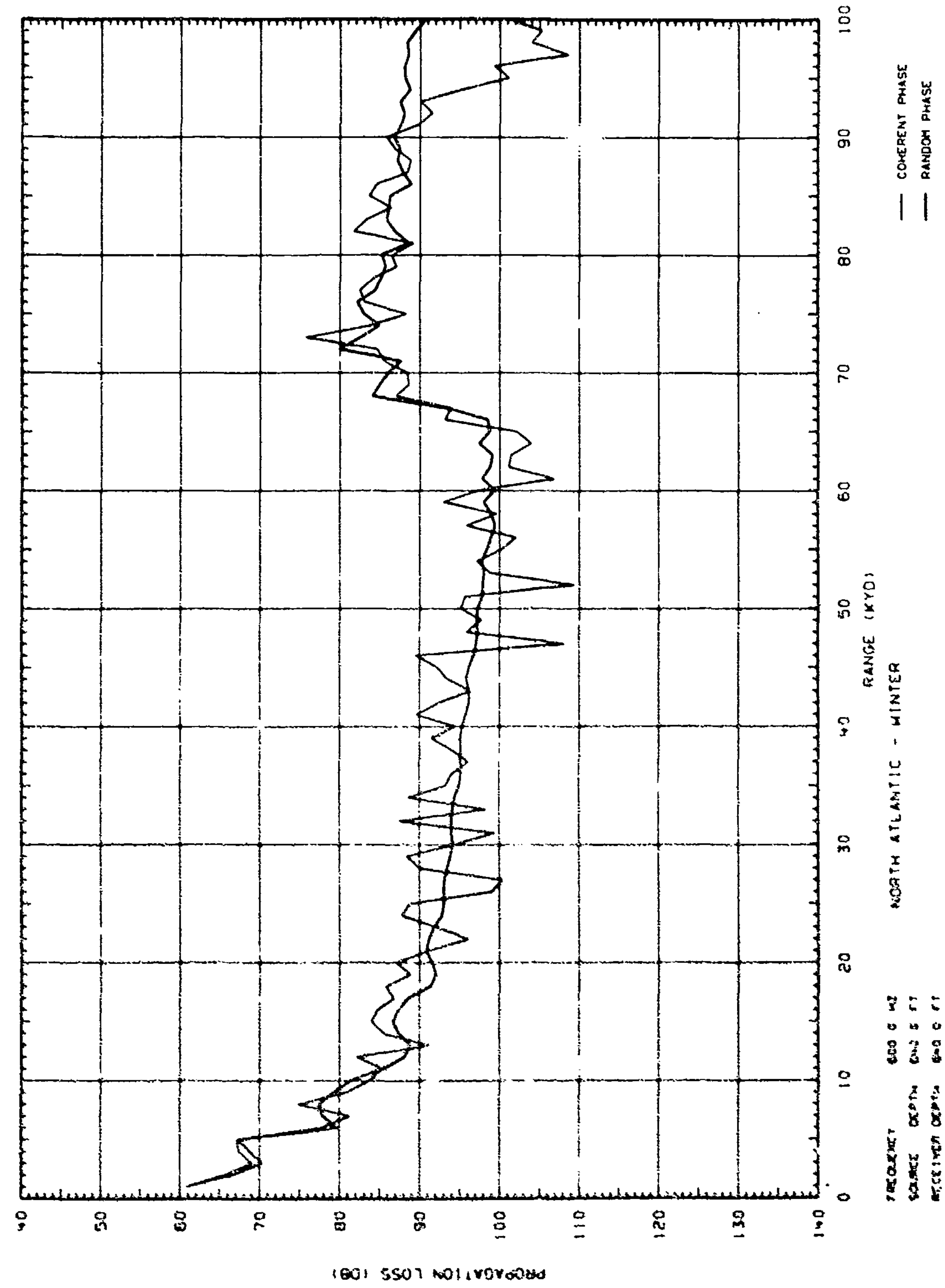

Figure 9. Propagation Loss Versus Range Computed by RAYMODE

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